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The impact of courtyard compact urban fabric on its shading: case study of Mosul city, Iraq

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Abstract

The courtyard pattern provides a comfortable environment in hot regions through supporting natural ventilation and protecting buildings from solar radiation. But, its performance depends on its urban fabric compactness as it affects surfaces' heat gain resulted from the solar radiation. The impact of urban compactness on urban shading is tested by simulating traditional compact and modern less compact neighborhoods in Mosul. Results from two sunlight simulation systems, Autodesk 3DS Max 2014 and LightUp Analytics, demonstrated that courtyard neighborhoods are nearly three times more compact than the modern neighborhoods. This leads to having five times larger shaded area, which helps to offer a more thermally comfortable environment.

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Keywords: Courtyard house; Environmental design strategies; Iraq; Mosul; Simulation; Urban compactness .

1. Introduction

The courtyard pattern is one of the oldest architectural forms. It had been used in hot regions around the world since the first old civilizations in Mesopotamia, Egypt, India and China until the middle of the last century [1, 2, 3, 4]. It includes having an open space in the building's core, which provides natural lighting and ventilation for the surrounding spaces, regulates the thermal conditions, and offers a private open space for occupants' interaction and activities [1, 4]. However, for various reasons, such as the development of the construction materials, the changing of the architectural styles, and the social, cultural and political changes [5,6], it has been replaced with new patterns

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of buildings, such as the detached and semi-detached buildings, which depend mainly on the electrical air-conditioning to provide a comfortable indoor environment. This has led to increasing the running costs, the energy consumption and buildings' negative impact on the environment [7]. Aiming at having more climatically, environmentally and economic buildings, many studies have investigated the thermal performance of the courtyard pattern in hot regions. Depending on their results, they have advocated readopting the courtyard pattern for being a thermally efficient solution for the hot climate [8, 9, 10].

The courtyard climatic efficient performance depends on using a number of elements including the courtyard, the wind-catchers, the thick walls and the basement [9, 11, 12]. They all work to apply two main environmental strategies: providing sufficient natural ventilation [13] and managing buildings exposure to the solar radiation, which includes providing shading [14]. The latter reduces heat gain, while the former helps to reduce the temperature [12, 15]. But, it is suggested that courtyard buildings might lose their thermal efficiency by being situated out of the traditional compact urban fabric, as they will have more exposed surfaces to the solar radiation and, as a result, get more heat gain [16]. For instance, as a detached building in a modern urban fabric, courtyard buildings might have an extra heat gain of up to 15% comparing with a square non-courtyard building of similar area [17]. Furthermore, it has been argued that urban compactness affects the whole urban fabric temperature, not just buildings, by increasing urban shading [12]. However, it has not been stated to which extent the proposed thermally efficient traditional compact urban fabric can increase the urban shading comparing with the new modern less compact urban fabric. Aiming at demonstrating this aspect and defining a thermally efficient built environment for the hot climate, this study focuses on determining the impact of urban fabric compactness on urban shading for its impact on the whole urban fabric thermal conditions. It analyzes a traditional compact urban fabric and a modern less compact one to show how a higher level of compactness can lead to a higher level of shading, which in turn helps to reduce the heat gain and to have a thermally comfortable environment.

2. Research aim and methodology

Aiming at analyzing the efficient thermal performance of the traditional compact urban fabric to be used in the future to develop a thermally efficient urban environment, this research determines the impact of urban fabric compactness on urban shading as it has a significant impact on buildings and urban temperature. To achieve this aim, the study adopted the experimental research method, as it is the research method that can help to analyze and determine variables' causal relationships. Mosul city in Iraq was selected as a case study; it has a hot climate and traditional compact and modern less compact urban fabrics. The experiment included doing a shading simulation for two neighborhoods in Mosul: a compact traditional neighborhood and modern grid-iron less compact one. Two simulation tools were used for the simulation purpose to have more integrated and confident results: LightUp Analytics and Autodesk 3D Max 2014. Both of them provide comprehensive simulation results depending on validated sunlight simulation systems. They simulate buildings shading with considering the correct sun angles and movement for simulation time, date and geographical location [18, 10, 20]. The measured indicators in the simulation included the compactness level and shading percentage and time in each of the two neighborhoods. The results included demonstrating how their compactness levels affect their shading.

3. Determining the impact of urban fabric compactness on shading

Two neighborhoods, a traditional compact one and modern grid-iron less compact one, from Mosul city, were selected and modeled based on Google map (Fig.1). The former is located in the old part of the city where courtyard buildings are attached to each other to form a compact urban fabric. The latter is located in the modern part of the city on the western bank of Tigris River. Buildings are of the modern patterns like the detached, semi-detached and row houses. In both of the two neighborhoods, buildings' height was assumed to be of two floors with a total height ranges between 7.5m to 8.0m, which is the most widespread height of residential buildings in Iraq, including Mosul [21, 22].

To simulate the shading, 3DS MAX 2014 and LightUp Analytics software were used, to get more comprehensive results. Using the 'Sunlight' function and the 'Daily sunlight' option in 3DS MAX 2014 and LightUp Analytics respectively (Fig.2), the shading level was simulated on the 31st of July, in which the temperature reaches one of its highest levels [23].

(a) The modern less compact urban fabric (b) The traditional compact urban fabric

Fig.1: The two selected neighborhoods for the simulation

The source: the Author based on (Google map)

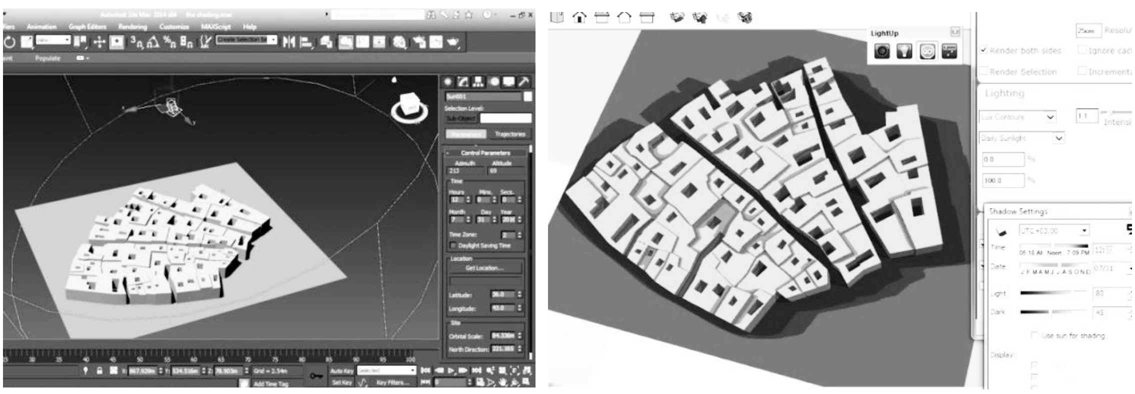
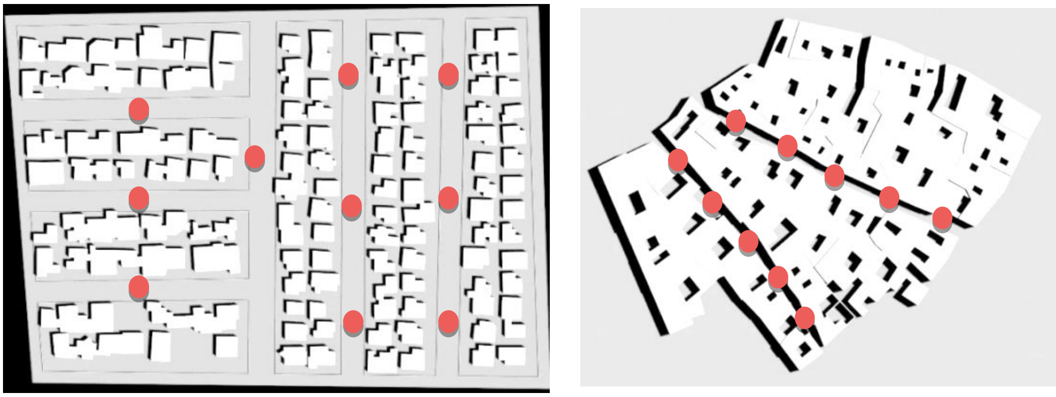


Fig.2. 3D MAX 2014 simulation (to the left) and LightUp Analytics (to the right)

To determine the impact of urban fabric compactness on shading, two kinds of measurements were taken for each of the two neighborhoods: the compactness level and the shading level. The former was measured through dividing buildings' footprint area over the total neighborhood area. Regarding the latter, to have a comprehensive analysis, several measurements were taken. At 12:00 PM on the 31st of July, when the sun reaches its highest altitude representing the extreme solar radiation, measurements included the percentage of the shaded area to the total neighborhood area (R1) and the percentage of the shaded area to the total open spaces areas (R2), which determine the overall urban shading. To find the impact of urban compactness on roads shading, the roads' average daily shaded area percentage (R3) and sunlit time were measured on the same day of first two measurements. Sunlit time was measured by taking the average of ten points in the middle of each neighborhood's roads (Fig.3).



(a) The modern less compact urban fabric (b) The traditional compact urban fabric

Fig.3: The shading layout of the two neighborhoods at 12:00 PM (3D MAX 14 results), and the sunlit time measurement points.

4. Results

The results illustrate that the two neighborhoods have different compactness and shading levels (Fig.3). Table (1) shows that the traditional courtyard urban fabric is around 2.5 times more compact than the modern grid-iron one. As a result, at 12:00 PM on the 31st of July, the percentage of the shaded area to the total area in the grid-iron neighborhood is 8%, while in the compact traditional one is 17%. Around two-thirds of the open areas in the traditional courtyard neighborhood are shaded in the middle of one of the hottest summer days in the city, while the shaded area is only one-tenth in the modern grid-iron neighborhood. The average percentage of roads' shaded area in the same day is 74.2% in the compact urban fabric and 14.16% in the less compact grid-iron one. Finally, roads' average sunlit time in the two neighborhoods is 1.86 hour in the courtyard compact one and 11.53 hours in the grid-iron one.

Table.1: The results of the simulation – The compactness and shading measurements

	The traditional neighbourhood	The modern neighbourhood
Buildings' footprint area (m^2)	4777.8	23342.5
Inside open spaces area (courts/gardens) (m^2)	756.6	31762.5
Outside spaces open area (roads) (m^2)	1128.2	23232.8
Total neighbourhood area (m^2)	6662.2	78337.8
Compactness level (%)	71.7	29.7
Total Shaded area (m^2)	1173.9	6877.7
Shading level at 12:00 (R1) (%)	17.6	8.7
Shading level at 12:00 (R2) (%)	62.2	12.5

Average daily shading level (R3) (%)	74.2	14.1
Maximum sunlight time (Hours)	3.3	12.5
Minimum sunlight time (Hours)	1.0	9.2
Average sunlight time (Hours)	1.8	11.5

Representing these data graphically, (Fig.4), demonstrates clearly to which extent the compact urban fabric is more shaded than the modern less compact one. The open spaces in the former are mostly shaded for most of the day, while in latter; they are slightly shaded for a limited time during the day. This difference in shading might explain on of the main reasons behind having a cooler urban environment in the courtyard compact neighborhoods than the modern less compact ones.

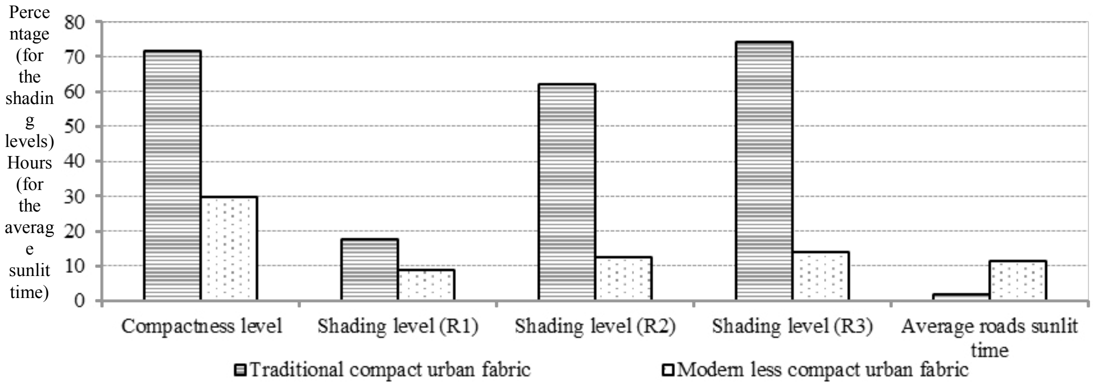


Fig.4: The Compactness level and shading indicators in the two neighborhoods.

5. Conclusions and Recommendations

The courtyard pattern has been advocated for being thermally efficient in hot climate regions. But, it is suggested that having the courtyard building in a compact urban fabric is one of the critical conditions of its efficient performance. The reason is that urban compactness affects buildings and the whole urban fabric thermal conditions through its impact on urban shading. This study demonstrated this impact through simulating the urban shading in a courtyard compact traditional neighborhood and a modern less compact grid-iron one. The simulation showed that the traditional compact urban fabric is around 2.5 times more compact than a modern less compact one. As a result, the former provides around two times larger overall shading area, around five times larger shaded area for the open spaces and around six times longer shading period for the roads than the latter.

Accordingly, whether courtyard buildings or modern pattern buildings are to be used, this paper recommends considering having a high level of urban fabric compactness to increase shading, to have a more thermally comfortable environment. For future studies, it recommends having further experimental studies on the courtyard pattern thermal efficiency and the environmental impact of each of its elements. This might include, for instance, investigating the impact of courtyard geometry on its thermal conditions. Furthermore, it would be useful to examine the possible opportunities to develop this pattern to be used for current and future buildings.

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References

[1] Sthapak, S., and Bandyopadhyay, A.: ‘Courtyard houses: An overview’, Recent Research in Science and Technology, 2014, 6, (1), pp. 70-73

[2] Muhaisen, A.S., and Gadi, M.B.: ‘Mathematical model for calculating the shaded and sunlit areas in a circular courtyard geometry’, Building and Environment, 2005, 40, (12), pp. 1619-1625

[3] Khan, M., and Majeed, H.M.: ‘Modelling and thermal optimization of traditional housing in a hot arid area (PhD thesis)’ (The University of Manchester, the UK, 2015. 2015)

[4] Edwards, B.: ‘Courtyard housing: Past, present and future’ (Taylor & Francis, 2006. 2006)

[5] Mohamad, N. (2012). "The traditoinal house between orginality and modernity." Journal of Engineering and Development 16(4): 13-32.

[6] Al-Thahab, A., et al. (2014). "Between Tradition and Modernity: Determining Spatial Systems of Privacy in the Domestic Architecture of Contemporary Iraq." International Journal of Architectural Research: ArchNet-IJAR 8(3): 238-250.

[7] Foruzanmehr, A.: ‘People's perception of the loggia: A vernacular passive cooling system in Iranian architecture’, Sustainable Cities and Society, 2015, 19, pp. 61-67

[8] Ratti, C., Raydan, D., and Steemers, K.: ‘Building form and environmental performance: archetypes, analysis and an arid climate’, Energy and Buildings, 2003, 35, (1), pp. 49-59

[9] Manioğlu, G., and Yılmaz, Z.: ‘Energy efficient design strategies in the hot dry area of Turkey’, Building and Environment, 2008, 43, (7), pp. 1301-1309

[10] Al Jawadi, M.: ‘Model of House Design Responsive to Hot-Dry Climate’, International Journal for Housing Science and Its Applications, 2011, 35, (3), pp. 171

[11] Behbood, K.T., Taleghani, M., and Heidari, S.: ‘Energy Efficient Architectural Design Strategies in Hot-Dry Area of Iran: Kashan’, Emirates Journal for Engineering Research, 2010, 15, (2), pp. 85-91

[12] Ali, H., Turki, D., Shaheen, R., and Bahjat, D.: ‘The Climatic Considerations for Planning & Architecture of the Traditional Arab City" Old City of Mosul, as a Model"’, Al-Rafadain Engineering Journal, 2013, 21, (1)

[13] Al-Hemiddi, N.A., and Megren Al-Saud, K.A.: ‘The effect of a ventilated interior courtyard on the thermal performance of a house in a hot–arid region’, Renewable Energy, 2001, 24, (3–4), pp. 581-595

[14] Muhaisen, A.S.: ‘Shading simulation of the courtyard form in different climatic regions’, Building and Environment, 2006, 41, (12), pp. 1731-1741

[15] Agha, R.: ‘Traditional Environmental Performance: The Impact of Active Systems upon the Courtyard House Type, Iraq’, Journal of Sustainable Development, 2015, 8, (8), pp. 28

[16] Gupta, V.: ‘Thermal efficiency of building clusters: an index for non air-conditioned buildings in hot climates’, Energy and urban built form, 1987, 133

[17] El-deep,K., El-zafarany, A., Sheriff, A. A.: ‘Effect of building form and urban pattern on energy consumption of residential buildings in different desert climate’. PLEA 2012, 28th conference opportunities, Limits and needs towards an environmentally responsible architect lima, Peru, 2012

[18] Reinhart, C., and Breton, P.-F.: ‘Experimental validation of Autodesk® 3ds Max® Design 2009 and DAYSIM 3.0’, Leukos, 2009, 6, (1), pp. 7-35

[19] Guglielmetti, R., Pless, S., and Torcellini, P.: ‘On the Use of Integrated Daylighting and Energy Simulations To Drive the Design of a Large Net-Zero Energy Office Building’. Proc. Innovation for our energey future, New York2010 pp. Pages

[20] LightUp Analytics Ltd, "LightUp Analytics," 2017. [Online]. Available: https://www.lightup-analytics.com. [Accessed 20 1 2017]

[21] Haydaran, R., K. T. , Alkurukchi, M., A. M. , and Aldewachi , M., H. D. : ‘Areal analysis of the traditional residential unit’s components in Mosul city, its relationship with their design attributes’, AL Rafdain Engineering Journal, 2007, 15, (1), pp. 96-111

[22] Aladdin, H., and Alsdjan, A.: ‘The shifts of the Iraqi housing in the first decade of the twenty-first century’, Journal of Engineering, 2013, 19, (2), pp. 1-18

[23] Ahmad, B., Ibraheem , Natheer, A., Mohammad, and Abdula , A.K., Shakir ‘A Study on Monthly and Annual Average Temperature Variations in Mosul’, in Editor (Ed.)^(Eds.): ‘Book A Study on Monthly and Annual Average Temperature Variations in Mosul’ (Mosul University, 2013, edn.), pp. 88-96